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EFFECTIVENESS OF PENSION SYSTEMS IN POST-SOVIET COUNTRIES – EVALUATION USING THE CCR MODEL

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1. Introduction

Efficiency allows you to create combinations. It is still understood as the actual productivity of the analyzed subject to its maximum production efficiency. Efficiency has found wide application in economics, not only in business operations. Almost all activities checked for efficiency and distribution. One of the oldest approaches to assessing effectiveness is based on indicators analysis[1]. Parametric methods are also used. However, using them, you must know the functional relationships that occur between input and output variables. Especially in public organizations, it is extremely difficult to assess the value of the results got. In practice, a non-parametric approach is often practiced. Among them, the Data Envelopment Analysis (DEA) method is very popular, which is operated in many areas, not only related to businesses or management[2]. Managing this one, assuming constant inputs, the researcher is able to find the most effective object in the group he analyzes based on empirical data.

Population aging and a systematic increase in the percentage of older people in society results in a greater financial burden on pension systems. Citizens require that, after years of paying social security contributions, they receive a decent retirement, which will make sure them adequate living conditions in old age. It is also important that society is aware of the destination of social security contributions[3]. These trends mean that the adequacy, stability and efficiency of pension systems will be checked more and more often. The mainly reasons is the control of existing policies and legal reforms so that these systems function better.

The purpose of this publication was to show the most effective pension system among post-Soviet states. The author did this using the CCR model, which belongs to the group of models from the DEA method. This action will allow further analyses to show the essential features of an effective pension system so

[1] One of the most popular indicators are: Jensen, Sharpe and Treynor.
[2] The DEA method has been used, among others in evaluation: pension funds (Jablonsky 2007), healthcare in Kenya (Kirigia et al. 2004), Australian universities (Abbot and Doucouliagos 2003) and in international comparative analyzes (Sengupta 2002).
[3] The ability to check your personal retirement account via the Internet is also gaining popularity.

that other post-Soviet countries can model it and reform it. Besides the critical analysis of the literature on the subject, the article uses statistical analysis measures and, in line with the goal, an analysis of effectiveness using the CCR model.

In the subsequent parts of the publication, interpretations of effectiveness are presented, the theoretical foundations of the DEA method are quoted, and have been showed the essence of the CCR model. Then, the process of the study was submitted, and the results got were discussed and it based the conclusions on them.

2. Efficiency

Efficiency is one of the key concepts in economics and is also a popular criterion for assessing functioning. The best-known term of efficiency among economists is the so-called Pareto optimum. It is a situation in which it is not possible to change production or distribution in such a way as to improve the situation of a certain group without deteriorating the situation of other entities (Varian 2010, pp. 15-16). Another approach that is also widespread in economics is Kaldor-Hicks effectiveness. It occurs when the profits of one group are higher than the losses incurred by another gather because of the changes made (Stringham 2001). On the other hand, in the DEA method, efficiency is defined as the ratio of weighted effects to the sum of weighted inputs.

According to Chybalski, analyses of the effectiveness of pension systems have become more important because the demographic dividend phenomenon is no longer present. He also indicates that the effectiveness of pension systems should be considered at two levels. The first is the micro-level, which refers to smooth consumption in life. The second is the macro-level, which concerns the current GDP distribution (Chybalski 2016, pp. 16-17). Góra and Palmer (2004, p. 3) point out that an effective social security system does not affect individual decisions regarding the division between work and leisure, as well as consumption and savings. What is important in such a system, the value of the premiums paid by the entity are equal to the value of the benefit that it may receive, after the account is liquidated, after a period of t.

3. Data Envelopment Analysis Method – theoretical aspect

The Data Envelopment Analysis method belongs to the group of nonparametric methods evaluating effectiveness. Using it, the researcher is able to estimate on the basis of data related to inputs and effects how the analyzed objects work in the examined group. This method assesses the efficiency of economic entities referred to as decision making unit (DMU).

The units that are being analyzed can be graphically represented using an efficiency curve (called: best practice frontier), which is estimated based on empirical data. Effective units are found on the curve and their efficiency is 1 (the Greek letter theta is usually used–θ). Ineffective objects are under the curve because they are dominated by effective objects. The level of their effectiveness is 1-θ.

It is important to be aware of the pros and cons of DEA. An undoubted plus is the fact that data with heterogeneous measures can be used for the analysis. The analysis using the DEA method also assumes the absence of a random component and also rejects the functional assumptions that exist between the studied variables. This allows estimating efficiency in the public sphere where it is difficult to determine the relationship between inputs and effects (the efficiency curve is estimated based on empirical data) (Thanassoulis 2003, pp. 227-250). Important, the DEA method allows you to use more than one input and output variable in the analysis, which is not allowed by traditional indicator methods. The analysis of empirical data in the DEA method also indicates factors that do not have a direct impact on the effectiveness of the entity (Thanassoulis 2003, pp. 227-250). It should be borne in mind, however, that the set level of efficiency can only be referred to the analyzed set. Any modification (adding or removing an object) will affect the results, so the researcher should be choose the exact number.

The undoubted disadvantage of the DEA method is also redundancy, i.e. the multiplication of effective solutions. Therefore, it is likely that several of the examined objects will be effective. The limitation, which may also be considered to some extent as a disadvantage, is the homogeneity requirement of the analyzed DMUs[4]. The condition of stability may also impede the analysis. A. Emrouznejad, G. Amin (2009, p. 489) point out that the standard DEA model is stable when:

$$n \geq \max\{m * s, 3(m + s)\} \tag{1}$$

Where n is the number of DMUs observed, and m and s are the number of entries and exits, respectively, In the development of the DEA method a great contribution was made, among others: Banker et al. (2004); Cook and Seiford (2009).

4. The essence of the CCR model

The CCR model was proposed by Charnes, Cooper and Rhodes in 1978, is the first model from the DEA group[5]. It considers efficiency in Farrell's sense, which allows the creation of a hierarchy of examined objects from the most to the least effective. The guiding idea of assessing the efficiency of facilities using the CCR model is to determine whether the technology that is used in the examinee facility best accomplishes the assumed tasks (Guzik 2009, p. 55). In addition, the CCR model allows you to create benchmarking formulas for facilities that have been ineffective, i.e. $\theta < 1$, and show results deficits or excess investments in them. All objects

[4] Polish researcher Guzik (2009) said that this is more because of the convenience of analysts than the needs of practice.

[5] For more on the origins of the DEA method and the beginnings of the CCR model, see Cooper et al. (2004, pp. 8-15).

considered effective, i.e. $\theta = 1$ in the CCR model are treated equally[6], which can be considered a minus of this model.

According to Tollo and Nalchigar (2008, pp. 597-598), the disadvantage of the CCR model may be the fact that it must be run n times, for each DMU, to calculate the efficiency of all facilities. They also believe that a permanent of scale may be a kind of trap, i.e. a proportional increase in outlays means a proportional increase in results.

If we compare the CCR model to the regression equation, we can see it that in both cases a larger number of explanatory variables will cause higher efficiency (coefficient of determination). However, increasing the number of variables in the CCR model will worsen the efficiency got or leave it unchanged. With regression equations, it is difficult to determine whether this will increase or decrease the determination coefficient. While comparing this model to the production function, in both cases the relationship between inputs and effects is analyzed.

5. Methodology of the research

The subject of the analysis is pension systems in the post-Soviet countries. The spatial scope of work is limited by the number of countries that arose after the collapse of the Union of Soviet Socialist Republics (USSR). They are Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Lithuania, Latvia, Moldova, Russia, Tajikistan, Ukraine, Uzbekistan. Turkmenistan was turned off for the lack of availability of data from the analysis. This study covers the years 2012, 2015 and 2018. Due to the fact that the literature recommends that the number of objects covered by the analysis exceed the number of inputs and results accepted for the study, three indicators have been analyzed – one input and two output (see Table 1). The adoption of relative values allowed the author to abstract, among others, on the size of the analyzed countries.

Table 1. Indicators used in the study

Name of the indicator	Role in the model
Insurance contribution for retirement security (in %)	Input
Replacement rate (in %)	Output
The value of an average pension in USD	Output

Source: Own study.

The author knows that he could take other variables as measures of inputs and results, which could change the order of the benchmark presented in Table 2. However, the

[6] To rank objects that have proved to be 100% effective, other models are used that are a development of the CCR model. An example can be models of hyper-efficiency, which were initiated by Andersen and Petersen (AP model) in 1993 (Andersen and Petersen 1993, pp. 1261-1264), which in later years were subject to numerous modifications. More about super-efficiency models, e.g. Esmaeilzadeh and Hadi-Vencheh (2013). Another method is even the cross-effectiveness used by Jahanshahloo et al. 2011). The classification of various methods for ranking objects analyzed by the DEA method was presented by Adler et al. (2002) and Aldamak and Zolfaghari (2017).

selection of variables was determined by data availability. From the expenditure side, the amount of the insurance premium for retirement security (in %) was adopted for analysis. The values discharged by both the employee and the employer have been added. This is due to the fact that in most common pension systems, both the employee and the employer pay the premium to secure old age. The analysis omits the contributions that are required to pay from farmers or self-employed persons, as they often have different conditions (e.g. percentage of declared income or a specific amount). From the effects side, the replacement rate was adopted, which is the relation of the average pension to the average salary in the economy. It was chosen by the author because it is used as a reference point in many international documents (e.g. International Labor Organization regulations). In addition, it is an effective indicator for comparative analyses. The author is aware of the disadvantages of this indicatior[7]. However, he believes that it allows a good comparison between countries that do not have one common database. The second indicator related to the effects of the pension system is the value of the average pension in a country. It has been converted from local currencies to USD at the average annual rate so a researcher can compare your retirement benefits. Thanks to this approach, it is easier to estimate in which of the analyzed countries pensions are the highest and the lowest.

Although in the literature one can come across an approach to compare the CCR model with the BCC model[8], the author has not decided on such an approach. The main reason is that the CCR model has more discriminatory power (it shows higher levels of inefficiency than the BCC model).

6. Evaluation of the effectiveness of pension systems in post-Soviet countries

When analyzing the efficiency coefficients calculated on the basis of input and output data for 2012, 2015 and 2018, it can be seen that the most effective pension systems in Armenia and Estonia. However, the pension system in Georgia was definitely the least effective (efficiency at 20%). In 2012, the system in Belarus was also among the most effective. Subsequently, it was possible to rank Kazakhstan and Russia. However, from the end of the ranking for 2012, Moldova, Tajikistan and Georgia can be qualified (respectively efficiency ratios of 0.227, 0.214 and 0.200). This year, 7 countries achieved an efficiency ratio higher both in relation to the average (0.605) and median (0.598).

In 2015, the most effective pension systems included those operating in Armenia, Estonia, and Lithuania. The Belarusian pension system deteriorated in relation to the analyzed systems and came in 5th place. Kazakhstan remained in the same position, although its performance indicator slightly deteriorated. However, analyzing the last three items in 2015, the same countries were again noted (only the order of Tajikistan

[7] About the imperfections of the replacement rate, among others Chybalski and Marcinkiewicz (2016).

[8] A model created by Banker et al. (1984) that assumes scale variability.

and Moldova changed). This year, the median efficiency ratio was higher than the average for this indicator (0.036 difference).

In 2018, only Armenian and Estonian were fully effective among the analyzed pension systems. The Lithuanian pension system has deteriorated significantly, which placed it 4th in the ranking. Significant drops also apply to Belarus and Russia (respectively from 5th to 9th and 6th to 10th). However, in 2018 significant improvements in efficiency ratios were also noted. Uzbekistan improved its position from 10th to 6th, and Azerbaijan from 7th to 5th This year also the median was higher than the average for the analyzed coefficients.

When analyzing the average of individual indicators[9] from 2012, 2015 and 2018, it can be concluded that the most effective pension systems (based on the variables adopted by the author) in post-Soviet countries occur in Armenia and Estonia. Systems in Lithuanian, Kazakh and Belarusian rank further. However, the last five positions in the created ranking included: Uzbekistan, Ukraine, Moldova, Tajikistan and Georgia (respectively efficiency ratios are 0.554, 0.411, 0.242, 0.232 and 0.200). It is worth noting that the highest average and median values for efficiency coefficients were achieved in 2015. At the same time, the standard deviation and coefficient of variation were the lowest.

Table 2. Values of efficiency coefficients and position in the ranking of individual post-Soviet countries in 2012-2018

	2012		2015		2018		Average	
	EC	Rank	EC	Rank	EC	Rank	EC	Rank
Armenia	1,000	1	1,000	1	1,000	1	1,000	1
Azerbaijan	0,491	9	0,673	7	0,772	5	0,631	6
Belarus	1,000	1	0,722	5	0,552	9	0,691	5
Estonia	1,000	1	1,000	1	1,000	1	1,000	1
Georgia	0,200	14	0,200	14	0,200	14	0,200	14
Kazakhstan	0,771	4	0,760	4	0,984	3	0,715	4
Kyrgyzstan	0,589	8	0,666	8	0,648	7	0,631	6
Latvia	0,607	7	0,602	9	0,599	8	0,603	8
Lithuania	0,728	6	1,000	1	0,831	4	0,836	3
Moldova	0,227	12	0,242	13	0,266	12	0,242	12
Russia	0,752	5	0,689	6	0,539	10	0,564	9
Tajikistan	0,214	13	0,246	12	0,241	13	0,232	13
Ukraine	0,450	10	0,493	11	0,268	11	0,411	11
Uzbekistan	0,438	11	0,589	10	0,672	6	0,554	10
Average	0,605		0,634		0,612		0,594	
Median	0,598		0,670		0,624		0,617	
Standard deviation	0,285		0,270		0,287		0,257	
Coefficient of variation (in %)	47,2		42,5		46,9		43,4	

Source: Own calculations based on data from statistical offices of individual countries.
Note: In the average column, the efficiency coefficient was calculated based on the average parameters for 2012, 2015 and 2018. EC means the efficiency coefficient.

[9] The author separately calculated the average for the amount of the insurance premium for retirement security, replacement rates and the average pension value in USD.

7. Conclusion

After analyzing the amount of the insurance premium for retirement security, replacement rates, as well as the value of the average pension in USD as variables of the CCR model, it was found that the most effective pension systems among post-Soviet countries exist in Armenia and Estonia. In all three analyzed years (2012, 2015 and 2018) they achieved 100% efficiency. Apart from them, Belarus (in 2012) and Lithuania (in 2015) were included in this group once. The average efficiency coefficient throughout the entire period exceeded 0.6. The least effective pension system was in Georgia, as the efficiency ratio was only 0.200. At the turn of the analyzed years, i.e. 2012-2018, two significant improvements in ranking position as well as two deteriorations can be listed. The improvement of the effectiveness of the pension system was noted primarily in Azerbaijan and Uzbekistan (from 9th to 5th and 11th to 6th, respectively). However, a significant reduction in the level of efficiency was observed in Belarus and Russia (from 1st to 9th and from 5th to 10th, respectively).

The results showed that the rulers of responsible pension systems in post-Soviet countries should look more at the solutions adopted in Armenia and Estonia. Implement similar activities in your countries, taking into account other conditions not included in the analysis, including the growth rate of the proportion of older people, cultural conditions can help reform functioning systems.

In further research, it is worth considering expanding the number of countries to be analyzed, e.g. by remaining countries from the Eastern Bloc, or by countries belonging to the European Union. According to the author, it is also worth considering in the next analyses of the effectiveness of pension systems the increase in the number of variables subject to examination. However, one should keep in mind the condition of stability of the DEA method, which was presented in part 3 of this article[10]. It is also worth considering the use of models other than CCR from the DEA group of methods.

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[10] It is suggested to introduce additional variables gradually, because the CCR model is not very selective in a situation when there is a large number of inputs and results.

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